

Claims

- [c1] 26. A silicon carbide structure suitable for use as a substrate in the manufacture of electronic devices such as light emitting diodes comprising:
- a silicon carbide wafer having a first and second surface and having a predetermined conductivity type and an initial carrier concentration;
- a region of implanted dopant atoms extending from said first surface into said silicon carbide wafer to a predetermined depth, said region having a higher carrier concentration than said initial carrier concentration in the remainder of said wafer; and
- an epitaxial layer on said first surface of said silicon carbide wafer.
- [c2] 27. A silicon carbide structure according to Claim 26 wherein said silicon carbide wafer comprises n-type 6H-silicon carbide.
- [c3] 28. A silicon carbide structure according to Claim 27 wherein said silicon carbide wafer is doped with nitrogen donor atoms.
- [c4] 29. A silicon carbide structure according to Claim 28

having a concentration of said nitrogen donor atoms of between about 5E17 and 3E18 cm⁻².

- [c5] 30. A silicon carbide structure according to Claim 26 wherein said region of implanted dopant atoms comprises phosphorus in a concentration of between about 1E19 and 5E21 cm⁻³.
- [c6] 31. A silicon carbide structure according to Claim 30 wherein said region of implanted dopant atoms comprises phosphorus in a concentration of about 1E21 cm⁻³.
- [c7] 32. A silicon carbide structure according to Claim 26 wherein said region of implanted dopant atoms comprises nitrogen in a concentration of between about 1E19 and 5E21 cm⁻³.
- [c8] 33. A silicon carbide structure according to Claim 32 wherein said region of implanted dopant atoms comprises phosphorus in a concentration of about 1E21 cm⁻³.
- [c9] 34. A silicon carbide structure according to Claim 26 wherein said silicon carbide wafer comprises n-type 4H-silicon carbide.
- [c10] 35. A silicon carbide structure according to Claim 26

wherein said region of implanted dopant atoms extends from said first surface into said silicon carbide wafer to a depth of between about 10 and 5000 Angstroms.

- [c11] 36. A silicon carbide structure according to Claim 35 wherein said region of implanted dopant atoms extends from said first surface into said silicon carbide wafer to a depth of between about 800 and 1000 Angstroms.
- [c12] 37. A silicon carbide structure according to Claim 35 wherein said region of implanted dopant atoms has a peak concentration of implanted dopant atoms of between about $1E19$ and $5E21\text{ cm}^{-3}$.
- [c13] 38. A silicon carbide structure according to Claim 37 wherein said region of implanted dopant atoms has a peak concentration of implanted dopant atoms of about $1E21\text{ cm}^{-3}$ and extends from said first surface into said silicon carbide wafer to a depth of about 500 Angstroms.
- [c14] 39. A silicon carbide structure according to Claim 26 wherein the peak concentration of implanted atoms in said implanted region occurs at or near the first surface of said silicon carbide substrate.
- [c15] 40. A silicon carbide precursor structure suitable for use as a substrate in the manufacture of electronic devices such as light emitting diodes comprising:

a silicon carbide wafer having a first and second surface and having a predetermined conductivity type and an initial carrier concentration;

a capping layer on said first surface of said silicon carbide wafer formed of a material that can be controllably deposited in thin layers, can be implanted with ions having the same conductivity as the silicon carbide wafer, and can be removed without substantially damaging the underlying surface of the wafer; and

a region of implanted dopant atoms extending completely through said capping layer and through said first surface into said silicon carbide wafer to a predetermined depth, said region having a higher carrier concentration than the initial carrier concentration in the remainder of said wafer.

- [c16] 41. A silicon carbide structure according to Claim 40 wherein said capping layer comprises a material selected from the group consisting of silicon nitride, silicon dioxide, and a metal.
- [c17] 42. A silicon carbide structure according to Claim 40 and further comprising an epitaxial thermal oxide layer on said silicon carbide wafer.
- [c18] 43. A silicon carbide structure according to Claim 41 wherein said capping layer has a thickness of about 500

Angstroms.

- [c19] 44. A silicon carbide structure according to Claim 41 wherein the thickness of said capping layer is selected to maximize the implant concentration resulting from implanting dopant atoms into and through said capping layer and into said silicon carbide wafer at or near said first surface of said wafer.
- [c20] 45. A silicon carbide structure according to Claim 40 wherein said region of implanted dopant atoms has a concentration of dopant atoms of about $1E21 \text{ cm}^{-3}$ and extends from said first surface into said wafer to a depth of about 500 Angstroms.
- [c21] 46. A silicon carbide precursor structure suitable for use as a substrate in the manufacture of electronic devices such as light emitting diodes comprising:
 - a silicon carbide wafer having a first and second surface and having a predetermined conductivity type and an initial carrier concentration;
 - a layer of silicon dioxide on said first surface of said silicon carbide; and
 - a region of implanted dopant atoms extending completely through said silicon dioxide layer and through said first surface into said silicon carbide wafer to a predetermined depth, said region having a higher carrier

concentration of dopant atoms than the initial carrier concentration in the remainder of said wafer.

- [c22] 47. A silicon carbide structure according to Claim 46 wherein said layer of silicon dioxide is about 500 Angstroms thick.
- [c23] 48. A silicon carbide structure according to Claim 46 wherein said implanted dopant atoms are nitrogen in a concentration of about $1E21 \text{ cm}^{-3}$ wherein said region of implanted dopant atoms extends from said first surface into said silicon carbide wafer to a depth of about 500 Angstroms.
- [c24] 60. A light emitting diode ("LED") comprising:
 - a silicon carbide wafer having a first and second surface and having a predetermined conductivity type and an initial carrier concentration;
 - a region of implanted dopant atoms extending from said first surface into said silicon carbide wafer for a predetermined distance, said region having a higher carrier concentration than said initial carrier concentration in the remainder of said wafer;
 - a conductive buffer region on said first surface of said conductive silicon carbide wafer;
 - an active region on said conductive buffer region;
 - a first ohmic contact to said active region; and

a second ohmic contact on the second surface of said silicon carbide wafer.

- [c25] 61. An LED according to Claim 60 wherein said active layer is a single heterostructure.
- [c26] 62. An LED according to Claim 60 wherein said active layer is a double heterostructure.
- [c27] 63. An LED according to Claim 60 wherein said active layer is a single quantum well.
- [c28] 64. An LED according to Claim 60 wherein said active layer is a multiple quantum well.
- [c29] 65. An LED according to Claim 60 wherein said silicon carbide wafer comprises n-type 6H-silicon carbide.
- [c30] 66. An LED according to Claim 65 wherein said initial carrier concentration of said silicon carbide wafer comprises nitrogen.
- [c31] 67. An LED according to Claim 66 wherein said carrier concentration of said nitrogen is about 5E17 to 3E18 cm⁻³.
- [c32] 68. An LED according to Claim 65 wherein said initial carrier concentration of said silicon carbide wafer comprises phosphorus.

- [c33] 69. An LED according to Claim 60 wherein said region of implanted dopant atoms comprises phosphorus atoms with an implant concentration of between about 1E19 and 5E21 cm⁻³.
- [c34] 70. An LED according to Claim 69 wherein said region of implanted dopant atoms comprises phosphorus dopant atoms with an implant concentration of about 1E21 cm⁻³.
- [c35] 71. An LED according to Claim 60 wherein said region of implanted dopant atoms comprises nitrogen dopant atoms with an implant concentration of between about 1E19 and 5E21 cm⁻³.
- [c36] 72. An LED according to Claim 71 wherein said region of implanted dopant atoms comprises phosphorus atoms with an implant concentration of about 1E21 cm⁻³.
- [c37] 73. An LED according to Claim 60 wherein said silicon carbide wafer comprises n-type 4H-silicon carbide.
- [c38] 74. An LED according to Claim 60 wherein said region of implanted dopant atoms extends from said first surface into said silicon carbide wafer to a depth of between about 10 and 5000 Angstroms.
- [c39] 75. An LED according to Claim 60 wherein said region of

implanted dopant atoms extends from said first surface into said silicon carbide wafer to a depth of between about 800 and 1000 Angstroms.

- [c40] 76. An LED according to Claim 60 wherein said region of implanted dopant atoms has a peak concentration of implanted dopant atoms of between about 1E19 and 5E21 cm⁻³.
- [c41] 77. An LED according to Claim 76 wherein said region of implanted dopant atoms has a peak concentration of implanted dopant atoms of about 1E21 cm⁻³ and extends from said first surface into said silicon carbide wafer to a depth of about 500 Angstroms.
- [c42] 78. An LED according to Claim 60 wherein the peak concentration of implanted atoms in said implanted region occurs at or near the first surface of said silicon carbide substrate.
- [c43] 79. A light emitting diode ("LED") comprising:
 - a silicon carbide wafer having a first and second surface and having a predetermined conductivity type and an initial carrier concentration;
 - a conductive buffer region on the first surface of said silicon carbide substrate;
 - a region of implanted dopant atoms having the same

conductivity as said wafer and extending from said first surface into said silicon carbide wafer for a predetermined distance causing a reduction of the overall forward voltage drop observable at the interface between said wafer and said conductive buffer region;
an active region on said conductive buffer region;
an ohmic contact to said active region; and
an ohmic contact on said second surface of said silicon carbide substrate.

- [c44] 80. An LED according to Claim 79 wherein said implanted region has a peak concentration of implanted dopant atoms of between about $1E19$ and $5E21\text{ cm}^{-3}$.
- [c45] 81. An LED according to Claim 79 wherein said implanted region has a thickness of between about 10 and 5000 Angstroms.
- [c46] 82. An LED according to Claim 79 wherein said implanted region has a peak concentration of implanted dopant atoms of about $1E21\text{ cm}^{-3}$ and is about 500 Angstroms thick.
- [c47] 83. An LED according to Claim 79 wherein said implanted region is doped with atoms selected from the group consisting of nitrogen and phosphorus.
- [c48] 84. An LED according to Claim 79 wherein said im-

planted region comprises phosphorus donor atoms implanted with first dose at a net dopant concentration of $2\text{E}15 \text{ cm}^{-2}$ at an energy of 25 keV and a second dose at a net dopant concentration of $3.6\text{E}15-2$ at an energy of 50 keV.

- [c49] 85. An LED according to Claim 79 wherein said region of implanted dopant atoms extends into said substrate to a depth of between about 800 and 1000 Angstroms.
- [c50] 86. An LED according to Claim 79 wherein said active region is a single heterostructure.
- [c51] 87 An LED according to Claim 79 wherein said active region is a double heterostructure.
- [c52] 88. An LED according to Claim 79 wherein said active region is a single quantum well.
- [c53] 89. An LED according to Claim 79 wherein said active region is a multiple quantum well.
- [c54] 90. An LED according to Claim 79 wherein said silicon carbide wafer comprises n-type 6H-silicon carbide having an initial ion concentration of nitrogen donor atoms of between about $5\text{E}17$ and $3\text{E}18 \text{ cm}^{-3}$ and wherein said region of implanted dopant atoms comprises phosphorus dopant atoms with an implant concentration of be-

tween about 1E19 and 5E21 cm⁻³ and is about 500 Angstroms thick.

- [c55] 91. An LED according to Claim 79 wherein said silicon carbide wafer comprises n-type 6H-silicon carbide having an initial ion concentration of nitrogen donor atoms of between about 5E17 and 3E18 cm⁻³ and wherein said region of implanted dopant atoms comprises nitrogen dopant atoms with an implant concentration of between about 1E19 and 5E21 cm⁻³ and is about 500 Angstroms thick.
- [c56] 92. An LED according to Claim 79 wherein said silicon carbide wafer comprises n-type 4H-silicon carbide having an initial ion concentration of nitrogen donor atoms of between about 5E17 and 3E18 cm⁻³ and wherein said region of implanted dopant atoms comprises phosphorus dopant atoms with an implant concentration of between about 1E19 and 5E21 cm⁻³ and is about 500 Angstroms thick.
- [c57] 93. An LED according to Claim 79 wherein said silicon carbide wafer comprises n-type 4H-silicon carbide having an initial ion concentration of nitrogen donor atoms of between about 5E17 and 3E18 cm⁻³ and wherein said region of implanted dopant atoms comprises nitrogen dopant atoms with an implant concentration of between

about 1E19 and 5E21 cm⁻³ and is about 500 Angstroms thick.